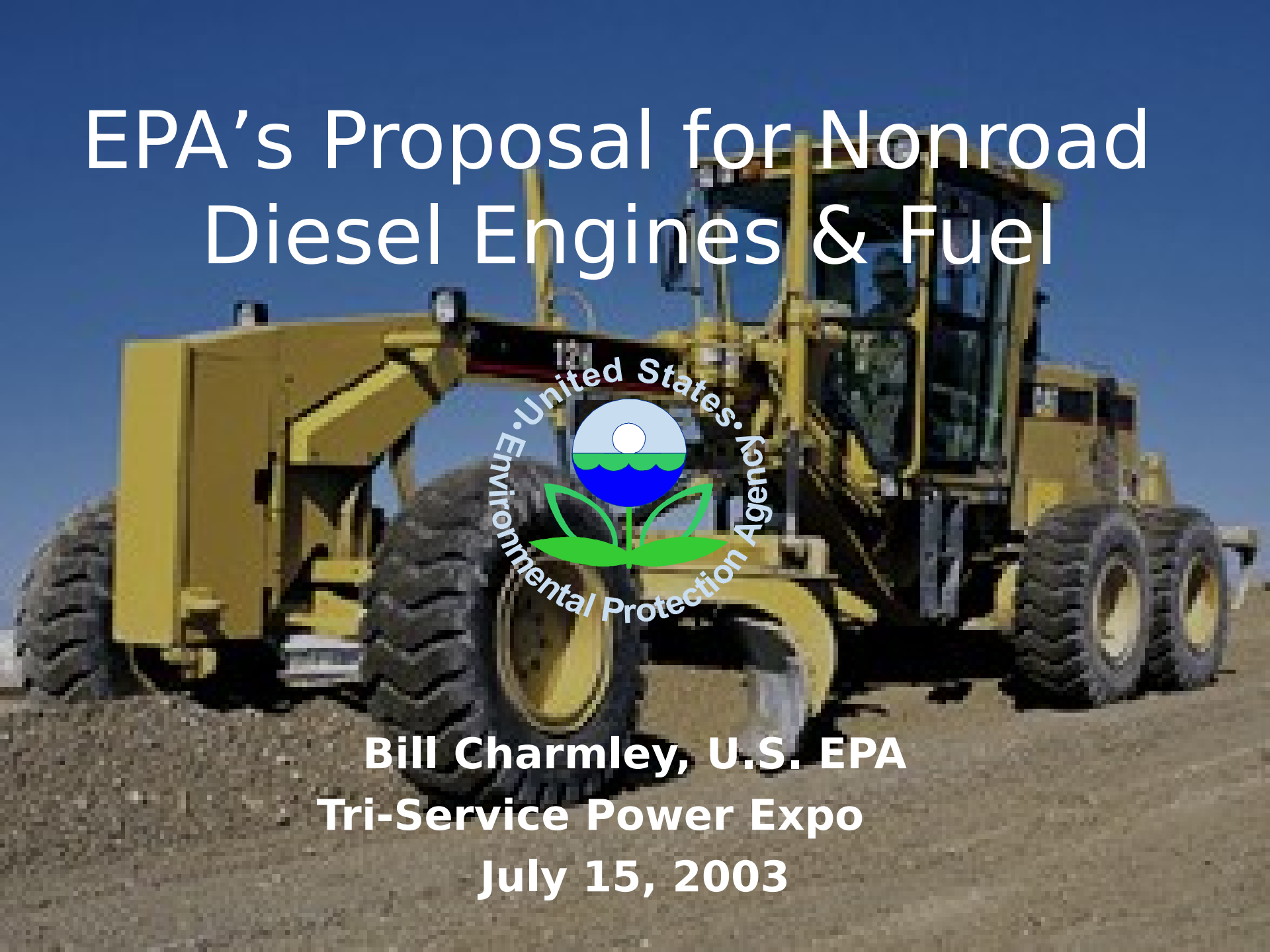
EPA's Proposal for Nonroad Diesel Engines & Fuel



Bill Charmley, U.S. EPA

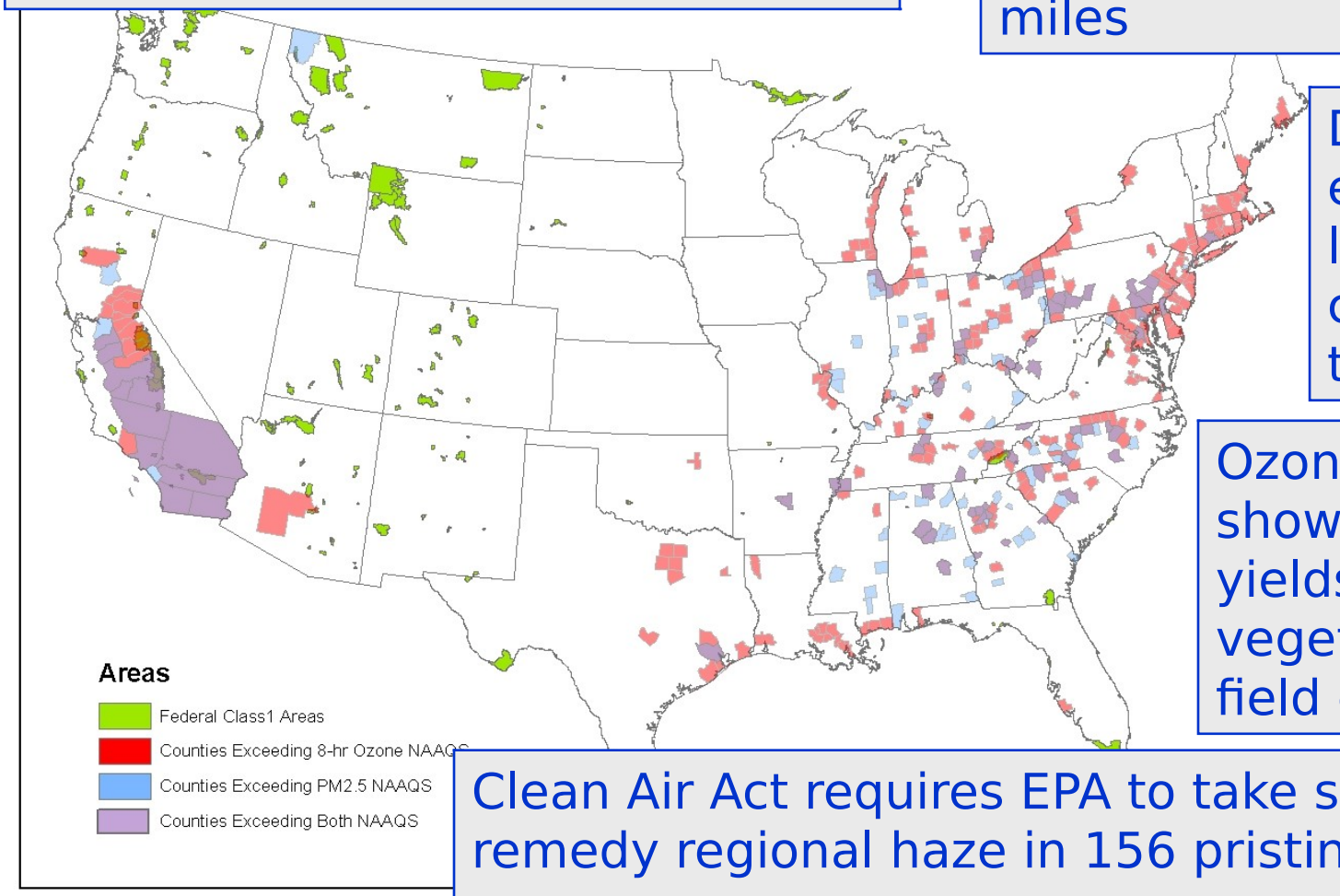
Tri-Service Power Expo

July 15, 2003

Widespread Need for Air Pollution

127 million people live in 353 counties that exceed the air quality standard for ozone or fine PM, or both

Fine particles from diesel exhaust can remain in the atmosphere for weeks, and carry over hundreds of miles

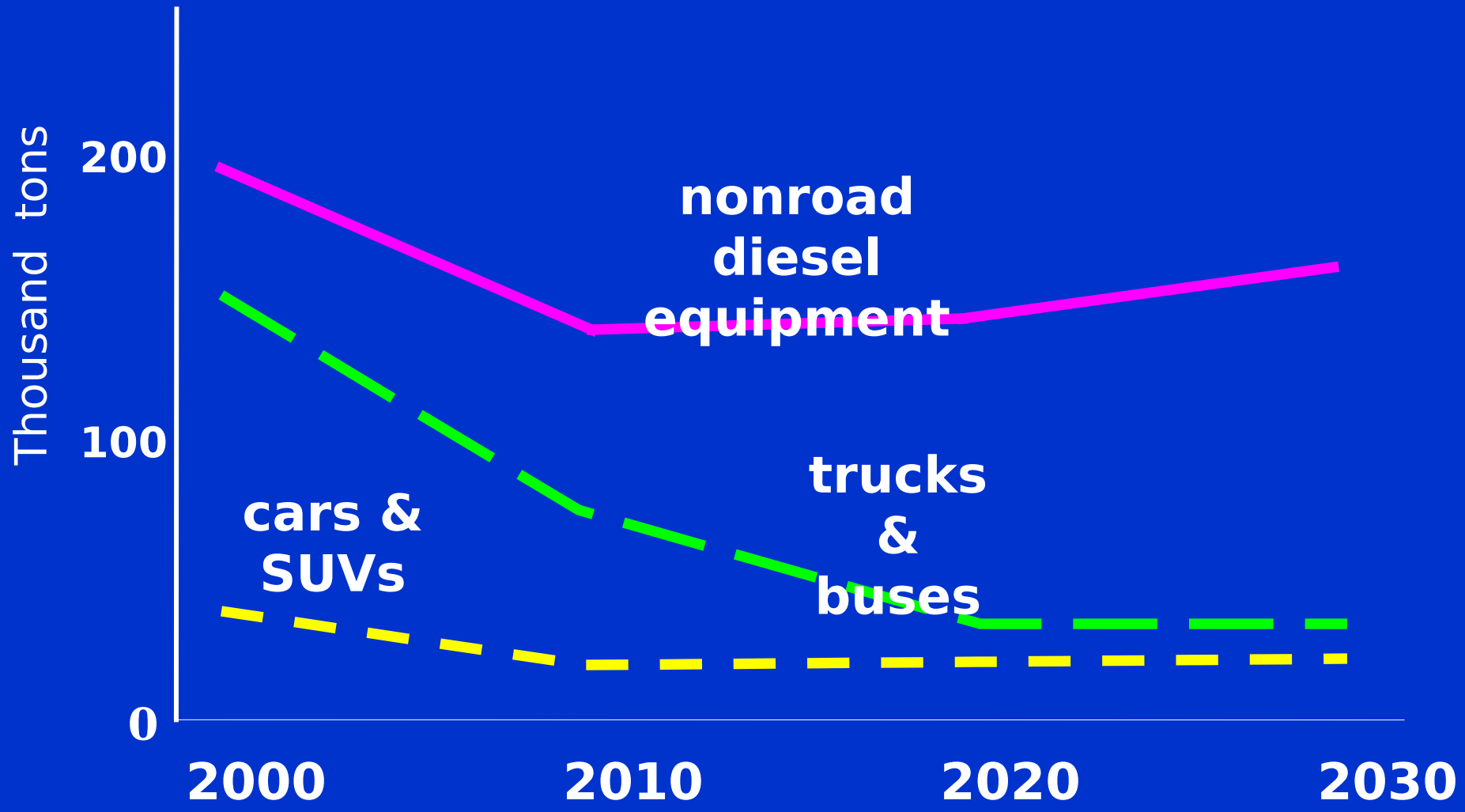


Diesel exhaust is likely to be carcinogenic to humans

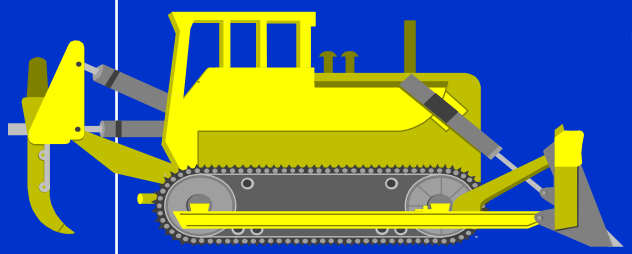
Ozone has been shown to reduce yields of vegetables and field crops

Clean Air Act requires EPA to take steps to remedy regional haze in 156 pristine “Class I” areas

Mobile Source PM



Phase-In of Nonroad Diesel Standards



Tier 1

Tier 2

Similar to highway 1998

Tier 3

Similar to highway 2004

Similar to highway 2007 (advanced aftertreatmer

new Tier 4 proposal

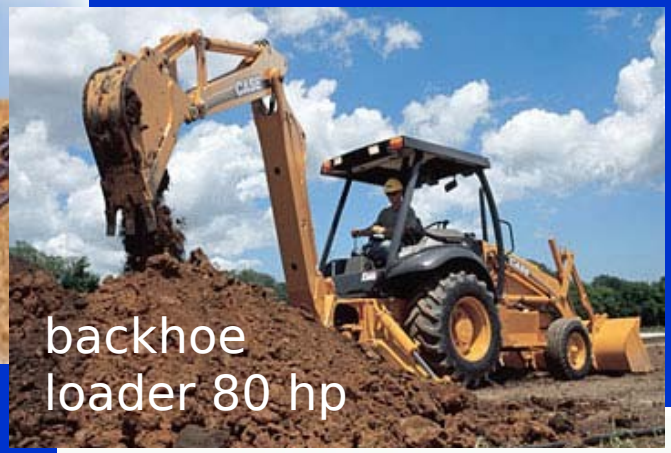
1996 1998 2000 2002 2004 2006 2008 2010 2012 2014

Controlling Nonroad Diesel Emissions Presents Some Challenges

- Extreme environmental conditions encountered
- Variety of operating patterns, engine sizes, packaging constraints
- Ruggedness demanded by users is often achieved by oversizing--cooler exhaust makes catalyst-based aftertreatment challenging.
- Nonroad diesel fuel is currently unregulated
  - contains upwards of ~3400 ppm sulfur
  - problematic for sulfur-sensitive control technologies

2WD tractor
130 hp

combine 285 hp

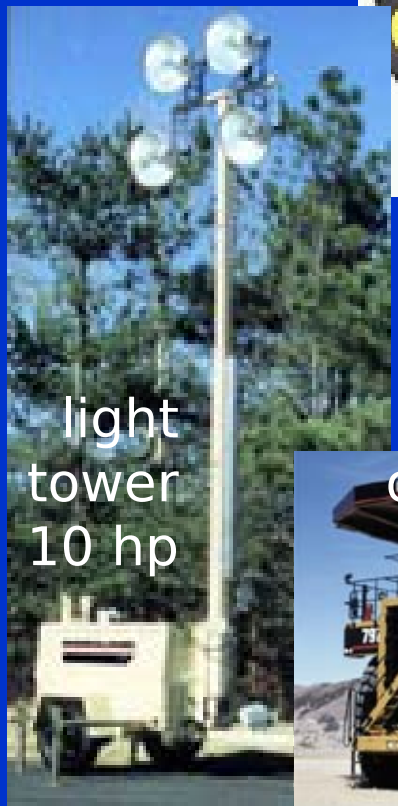


backhoe
loader 80 hp

trencher
50 hp

utility
vehicle
18 hp

skid steer
loader
80 hp



light
tower
10 hp

genset
20 hp

mini-
track
loader
20 hp

off-highway
truck
1000 hp

Tier 4 Program Considerations

- Treat the diesel fuel and engine as a system.
- Transfer advanced technology from 2007 highway program to nonroad applications.
- Provide 6-10 years lead time for fuels and engines.
- Include flexibility provisions to minimize costs.
- Avoid interference with implementation of 2007 highway diesel program (put in place by EPA in 2001).

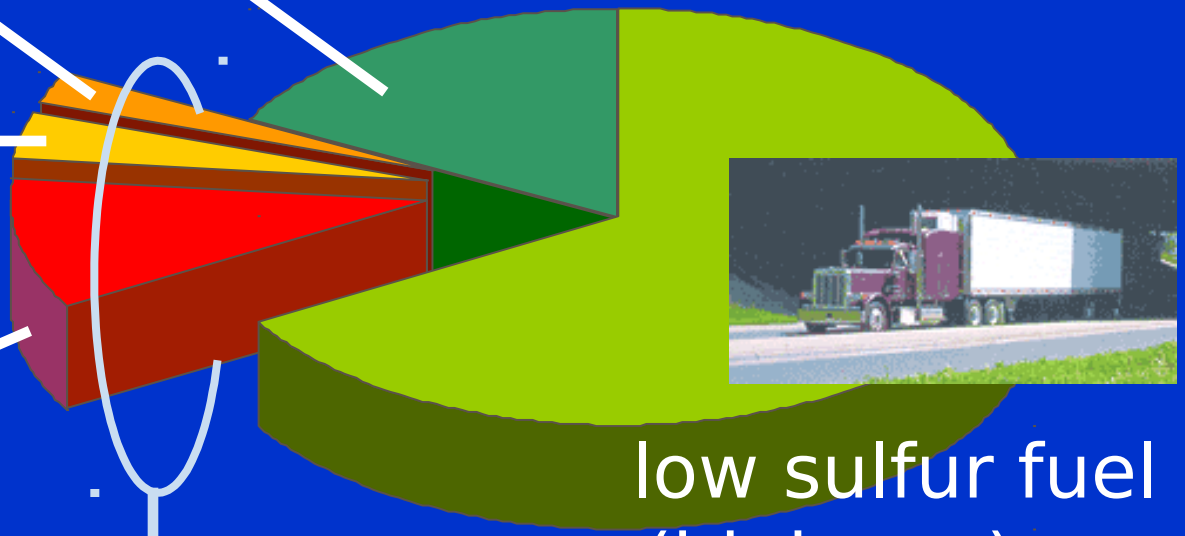
Distillate Fuels

home heating, etc 17%
not covered

marine 2.5%

locomotive 3.5%

nonroad equipment 10%



low sulfur fuel (highway) 67%
regulated since 1993

covered by the proposal

Today

NOx *(g/hp-hr)*

PM *(g/hp-hr)*

fuel

8 7 6 5 4 3 2 1

0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1

NOx

PM

Tier 1

Tier 1-2

Tier 2

Tier 1

<25 hp

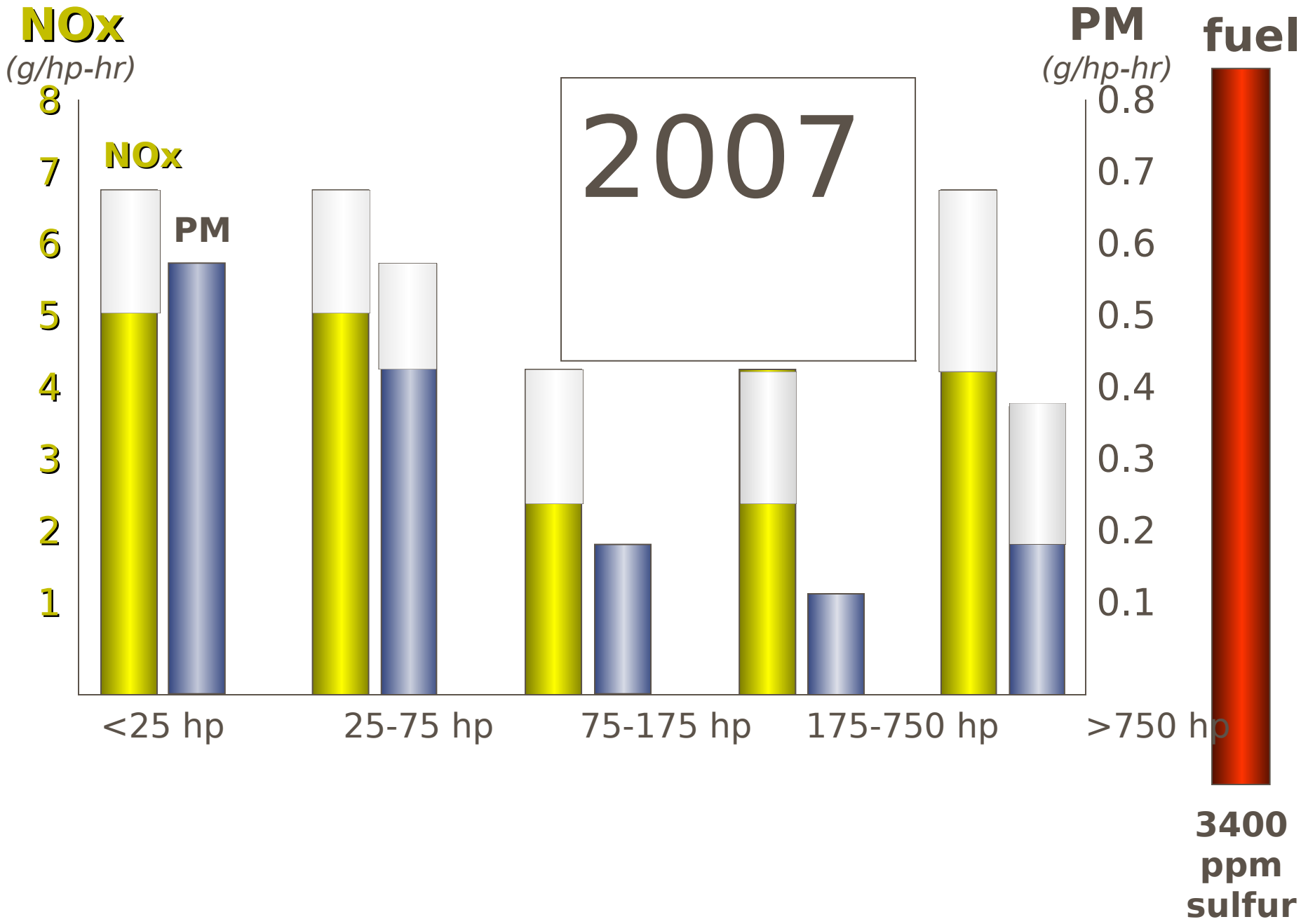
25-75 hp

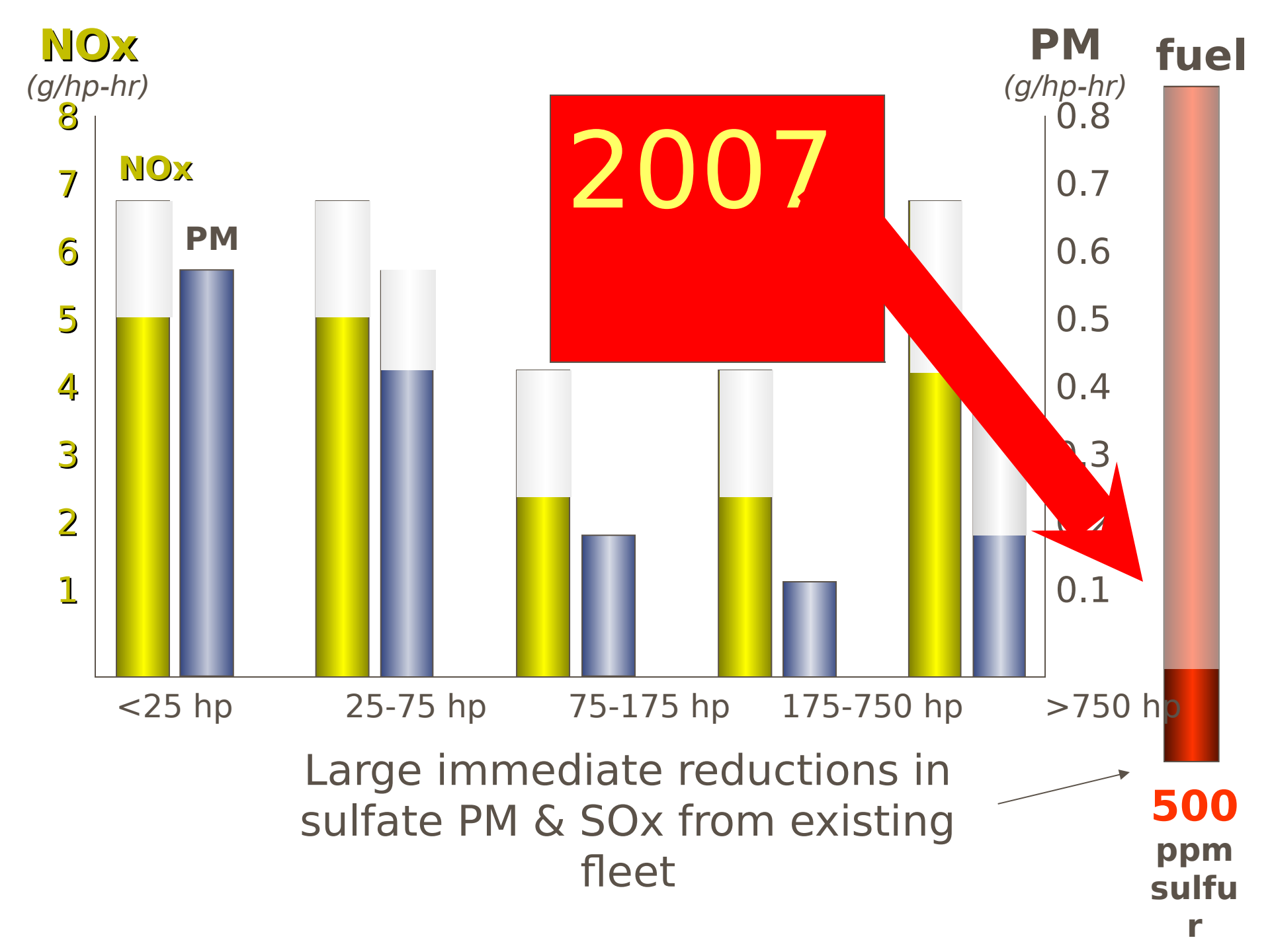
75-175 hp

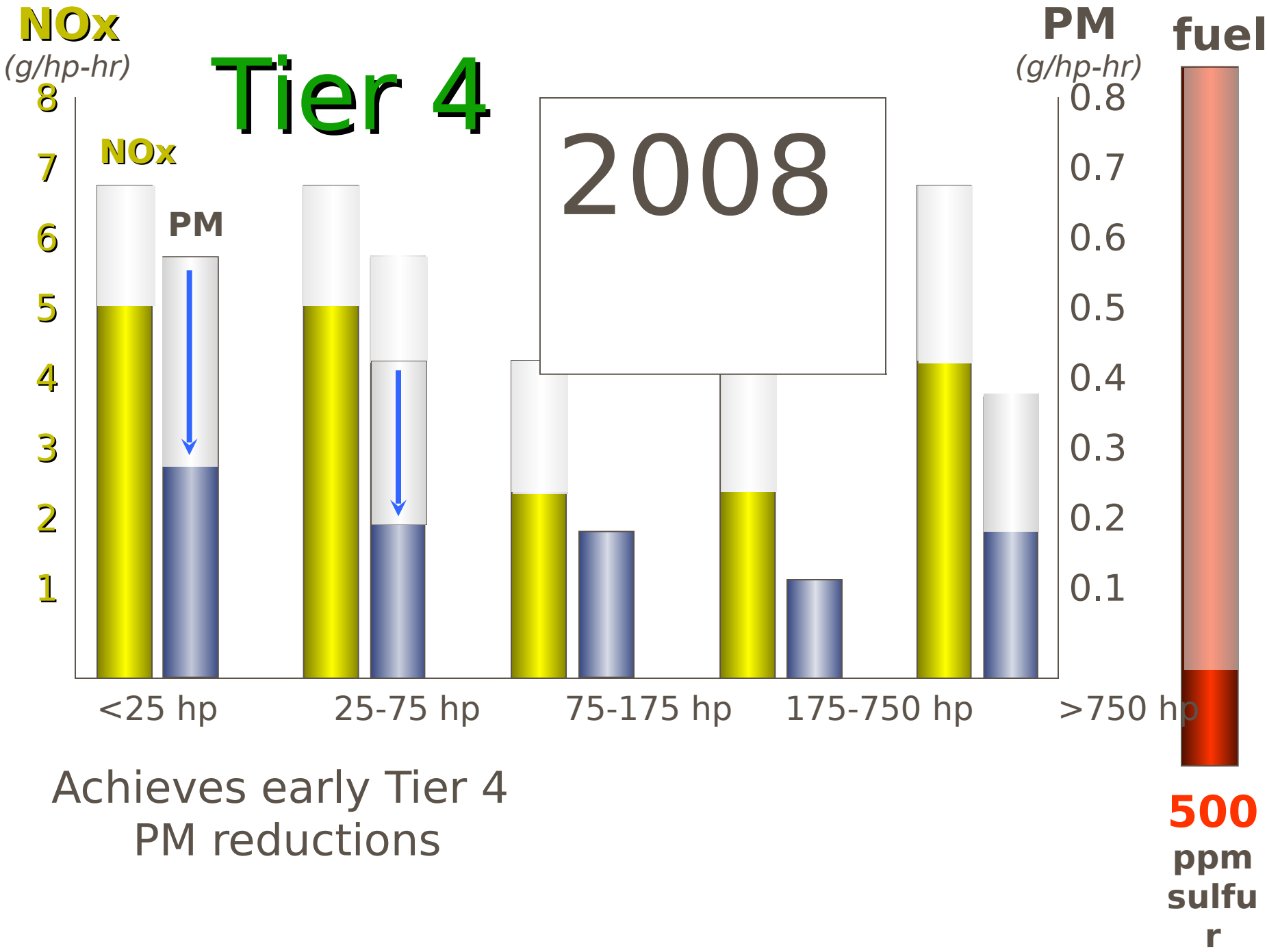
175-750 hp

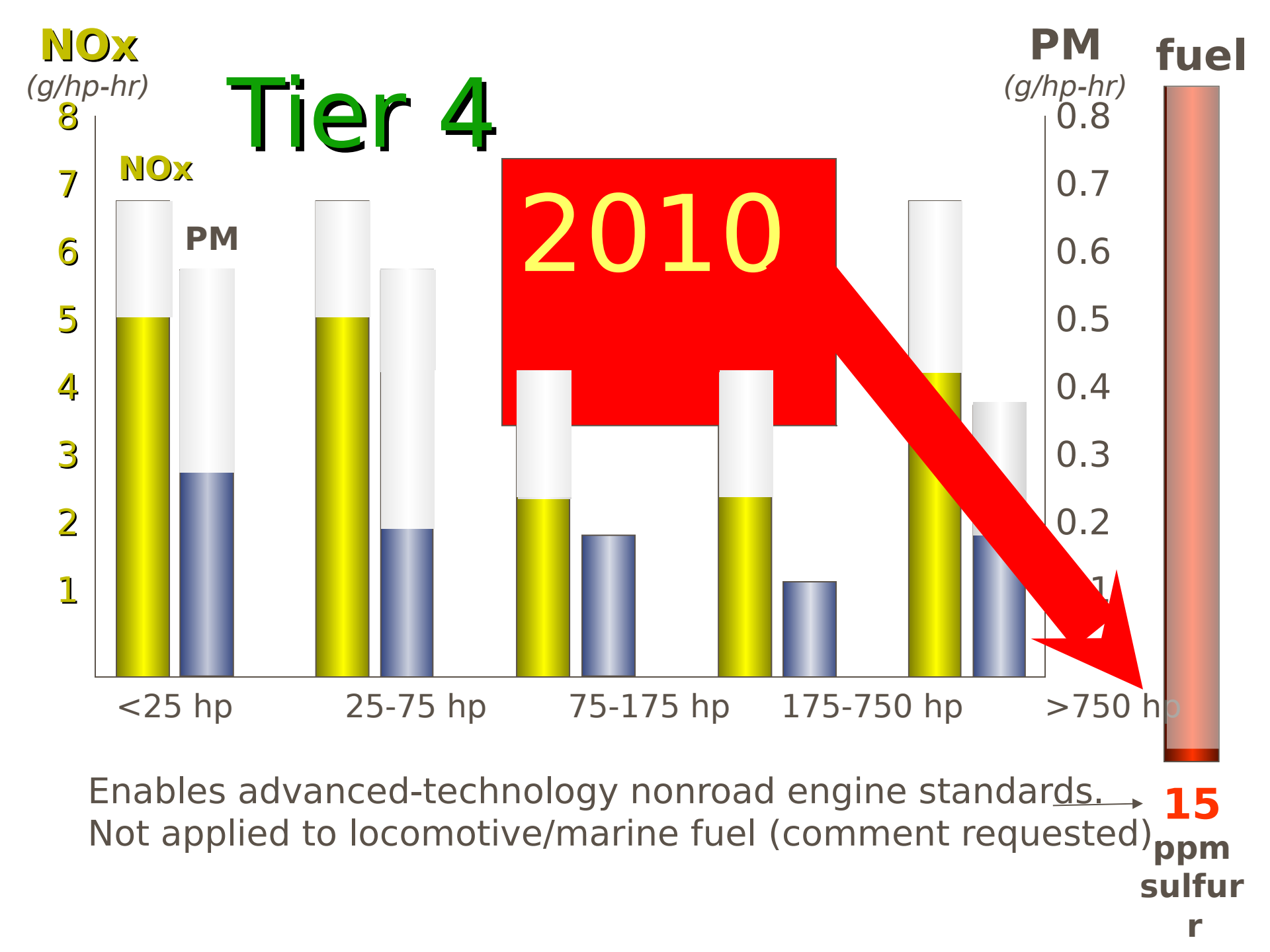
>750 hp

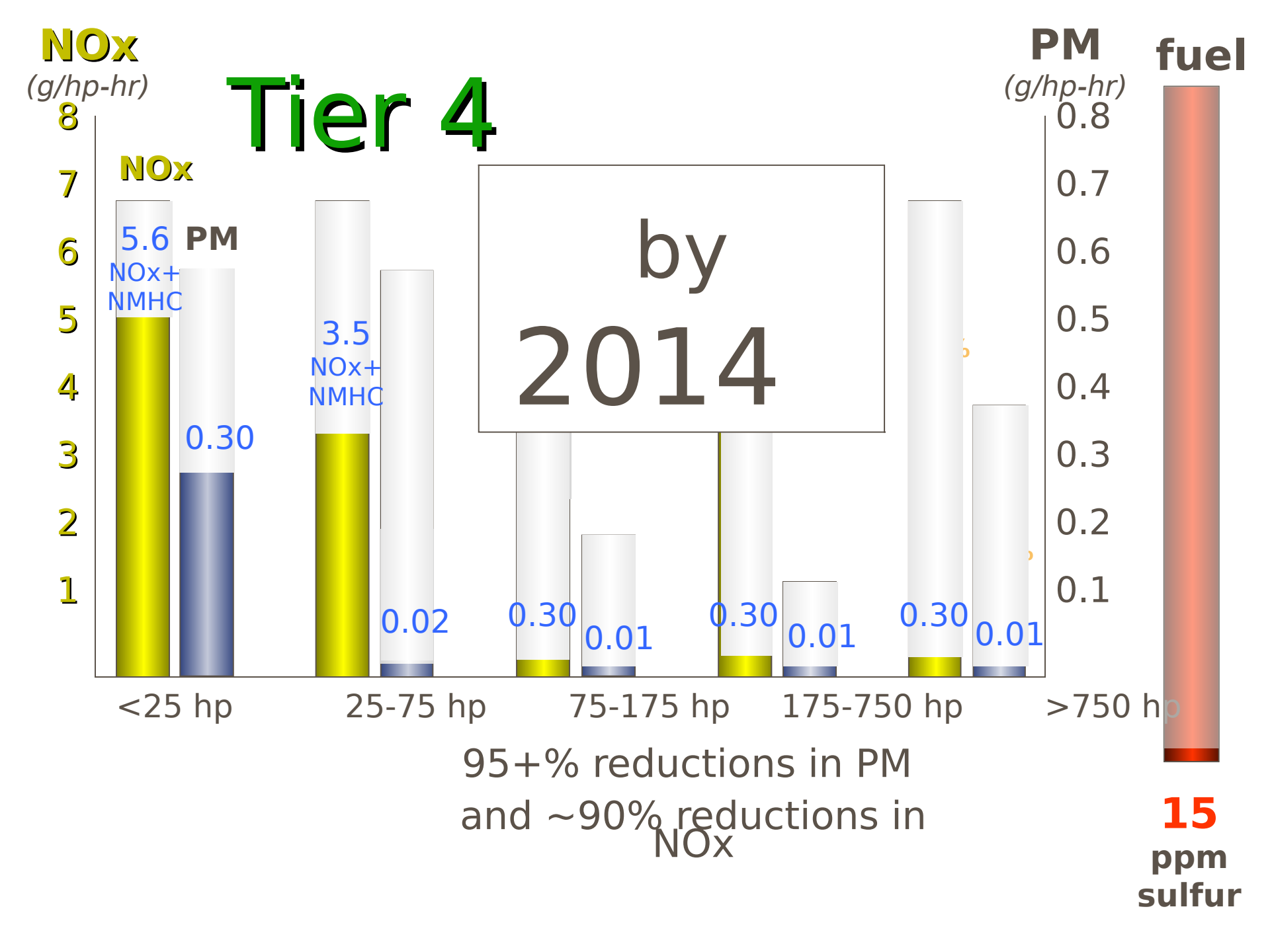
3400 ppm sulfur


NOx
(g/hp-hr)
PM
(g/hp-hr)
fuel
2007
NOx
PM
8
7
6
5
4
3
2
1
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
<25 hp
25-75 hp
75-175 hp
175-750 hp
>750 hp
3400
ppm
sulfur

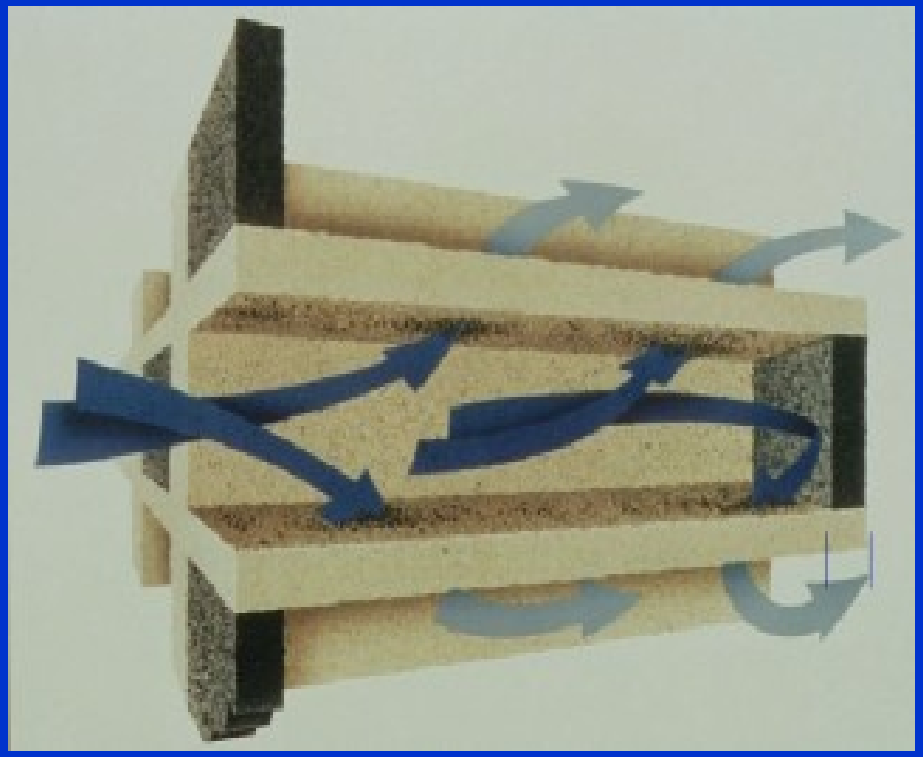

NOx
(g/hp-hr)
PM
(g/hp-hr)
fuel
8
7
6
5
4
3
2
1
0.8
0.7
0.6
0.5
0.4
0.1
NOx
PM
2007
<25 hp
25-75 hp
75-175 hp
175-750 hp
>750 hp
Large immediate reductions in sulfate PM & SOx from existing fleet
500
ppm
sulfu
r


NOx
(g/hp-hr)
Tier 4
NOx
PM
2008
PM
(g/hp-hr)
fuel
8
7
6
5
4
3
2
1
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
<25 hp
25-75 hp
75-175 hp
175-750 hp
>750 hp
Achieves early Tier 4
PM reductions
500
ppm
sulfu
r


NOx
(g/hp-hr)
Tier 4
NOx
PM
2010
PM
(g/hp-hr)
fuel
8
7
6
5
4
3
2
1
0.8
0.7
0.6
0.5
0.4
0.3
0.2
<25 hp
25-75 hp
75-175 hp
175-750 hp
>750 hp
Enables advanced-technology nonroad engine standards.
Not applied to locomotive/marine fuel (comment requested)
15
ppm
sulfur
r


NOx
(g/hp-hr)
Tier 4
NOx
PM
(g/hp-hr)
fuel
8
7
6
5
4
3
2
1
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
5.6
NOx+
NMHC
PM
0.30
3.5
NOx+
NMHC
0.02
0.30
0.01
0.30
0.01
0.30
0.01
by
2014
<25 hp
25-75 hp
75-175 hp
175-750 hp
>750 hp
95+% reductions in PM
and ~90% reductions in
NOx
15
ppm
sulfur

Catalyzed Diesel Particulate Filter



Mechanical Filtration of PM
(~ like an air filter in your house)

Holds soot in the excess O_2 exhaust until it can be oxidized
(~ provides residence time for soot to burn)

Soot burn rate $\geq$ soot accumulation rate or filter will "plug"

Catalyst promotes faster burn

Catalysts are sulfur sensitive
- oxidize sulfur to sulfate PM
- are poisoned by sulfur

A vivid demonstration of what this is all about

- Typical test filter – current standards
- Test filter – Tier 4 PM standards
- Unused test filter

Catalyzed Diesel Particulate Filters

- Catalysts are used to
  - promote oxidation of gas phase HCs (otherwise would condense in the atmosphere)
  - promote direct oxidation of PM on the filter surface
  - promote oxidation of NO to NO_2 (a strong oxidant) which oxidizes PM

- The catalysts needed to promote PM oxidation are sulfur sensitive
  - sulfur compounds poison the catalyst limiting their effectiveness
  - sulfur is oxidized by the catalyst to form sulfate PM
    - sulfur conversion rate to sulfate PM goes from 2% engine out to >40% cat out
    - sulfate PM is the primary PM emission from CDPFs

NOx Adsorber Catalysts (bi-modal operation)

3-way-catalyst + storage component

- Lean (excess O_2 / typical diesel) Operation
  - NOx is stored on the catalyst surface as a metallic nitrate
  - HCs and CO are oxidized to CO_2 and H_2O
  - Emission control can approach 100% effectiveness
  - But, only so much NOx can be stored before the catalyst is "full"
    - at idle can store for extended periods > 10 minutes
    - at high power (high NOx mass flow) ~1 minute

- Regeneration - Rich (O_2 deficit/not unlike gasoline) Operation
  - NOx is released from the catalyst surface
  - In the absence of oxygen the NOx is reduced by reductants in the exhaust (HCs, CO, H_2) across a "3-way" catalyst function
  - NOx emission control in this mode can be in excess of 90%

NOx Adsorber Catalysts Require Low S Fuel

- Sulfur in diesel fuel
  - Sulfur emissions, like NOx emissions, are stored on the surface of the NOx adsorber catalyst as metallic sulfates
  - The metallic sulfates that are formed are extremely stable and are not removed by NOx regeneration
  - A separate SOx regeneration (desulfation: high temperature regeneration) can remove the sulfur but repeated desulfations can damage catalysts
  - To minimize damage from desulfation fuel sulfur levels must be low
- Require electronic control systems for regeneration
  - Current NR diesel engines are not designed to provide this function
  - Tier 3 diesel engines will have engine fuel system and air handling systems that can form the basis for the required Tier 4 controls
  - On-highway 2007 control approaches (algorithms) will apply to nonroad as well

Clean Diesel Technologies

- CDPFs can virtually eliminate diesel PM
  - Can achieve gasoline like levels or lower
  - Requires low sulfur diesel fuel
  - May require supplemental heat to promote soot oxidation
  - We have projected regeneration system technologies for all Tier 4 nonroad engines (>25 hp) based on Tier 3 engine control technologies

- NOx Adsorbers can reduce diesel NOx by more than 90 percent
  - Similar to gasoline TWC levels
  - Requires low sulfur diesel fuel
  - Requires integration with engine hardware based on Tier 3 developments, control algorithms from on-highway HD2007

Provisions to Reduce Economic Impacts

- **Gradual, coordinated phase-in of the Tier 4 standards to:**
  - maximize technology transfer from 2007 highway program
  - address redesign workload for diesel engines and machines
- **Additional lead time** for small refiners/engine manufacturers.
- **Early credits** to encourage companies to meet requirements early.
- **Averaging, Banking, & Trading** provisions for engine companies.
- **Up to 7 years additional lead time** given to equipment manufacturers for small-volume products.
- **Companies may petition EPA for relief** if the burden of the regulations would cause severe economic hardship.

Cost Impacts for Engine & Equipment Manufacturers

- Costs vary with engine size and equipment application.
- Some typical examples:

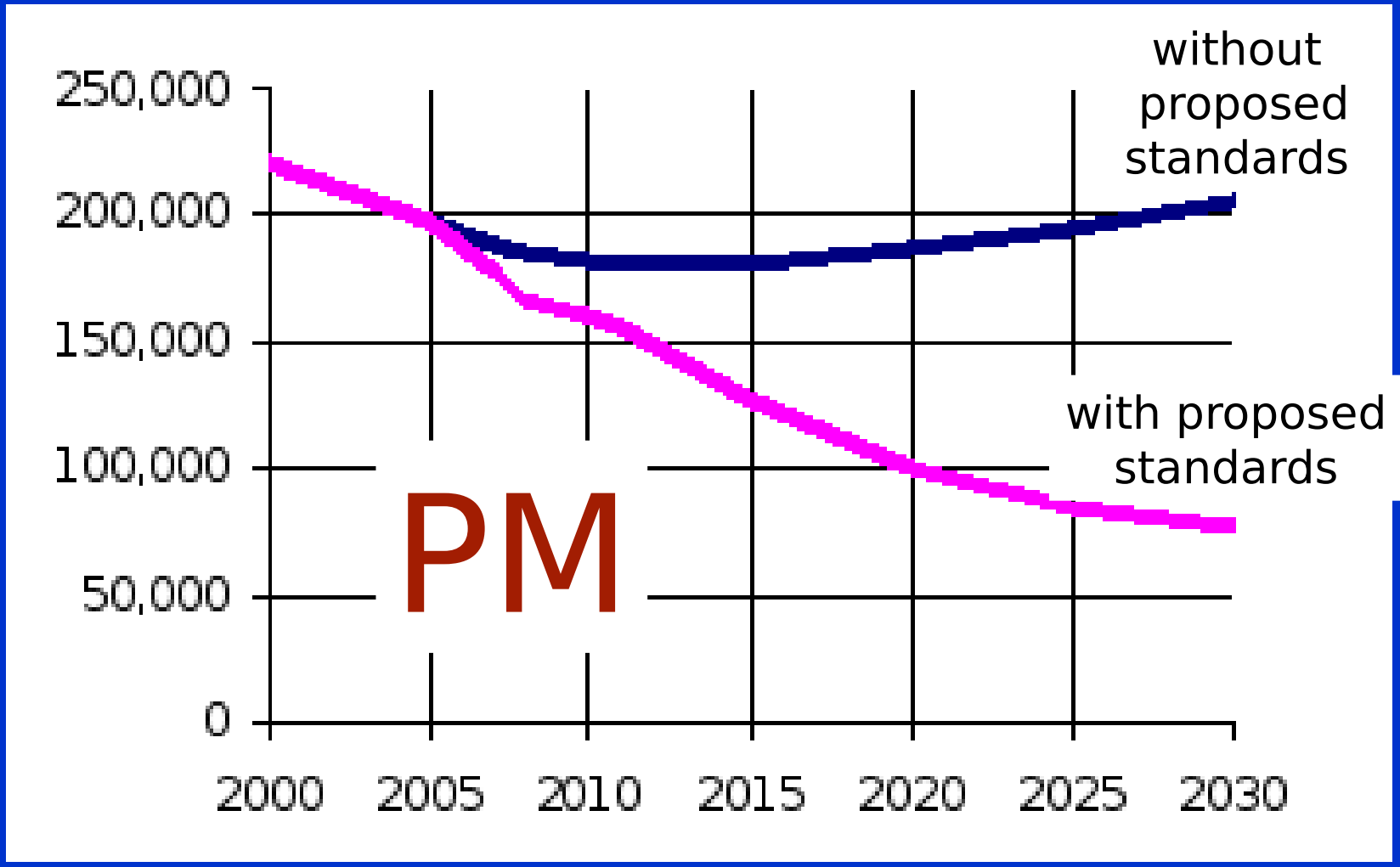
Diesel Fuel Refiner, Distributor, & User Impacts

- Average fuel cost (refining, distribution, & lubricity additive): **4.8 ¢/gal**
- Maintenance savings to nonroad equipment operator from cleaner fuel: **3.3**
- Net consumer cost of fuel change: **1.5 ¢/gal**

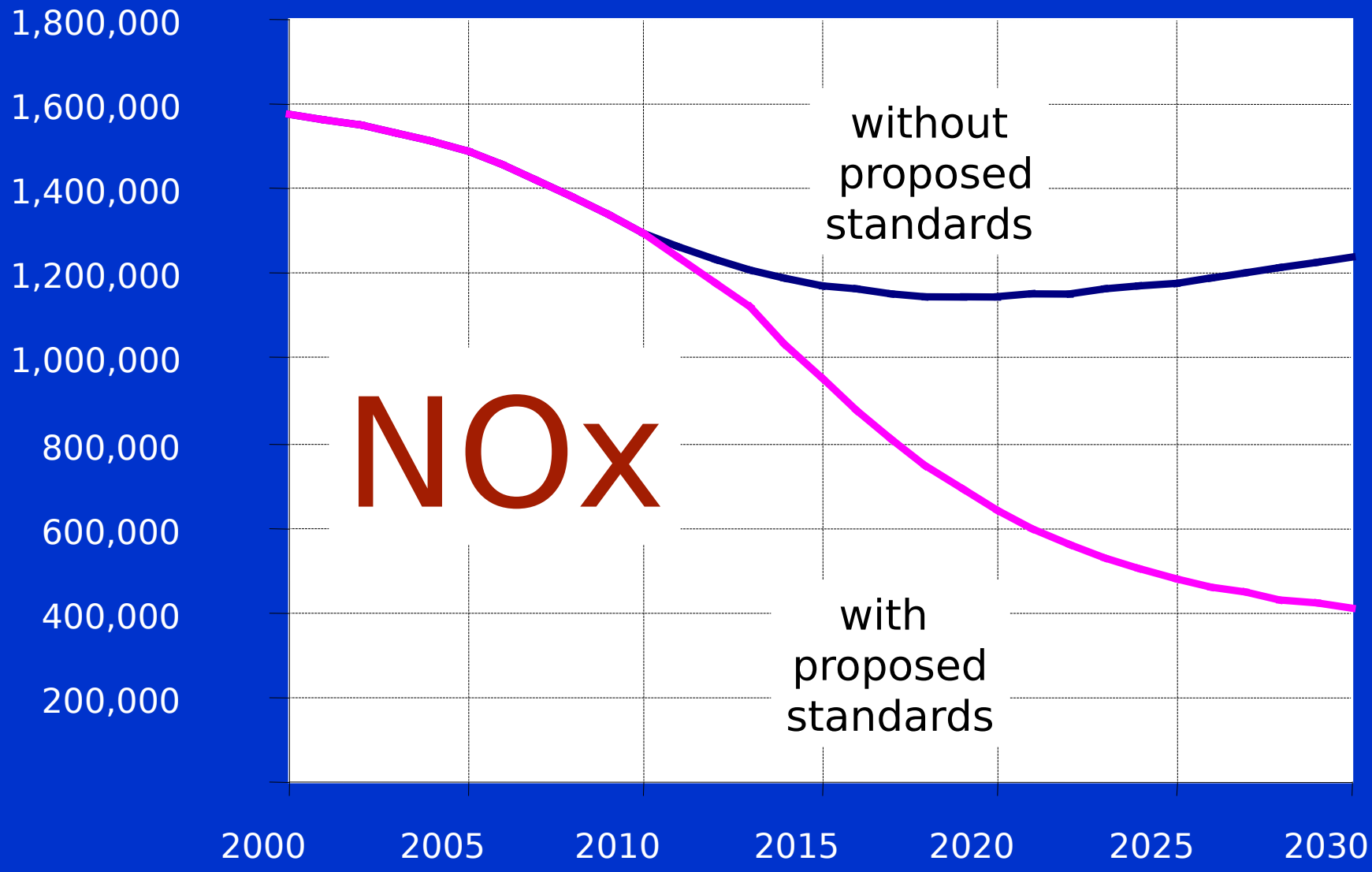
- Fuel costs expected to vary by region of the country (3.0 to 8.9 ¢/gal)

Nationwide PM Reductions From Nonroad Diesels

(PM2.5 tons/year)



Nationwide NOx Reductions From Nonroad Diesels (tons/year)



Benefits

- ***The program will prevent annually:***
  - 9,600 premature deaths
  - 16,000 nonfatal heart attacks
  - 5,700 cases of chronic bronchitis
  - 8,300 hospital admissions
  - 14,000 annual acute bronchitis attacks in children
  - nearly 1 million lost work days
- Comparable to benefits of 2007 highway truck program
- Will also help improve visibility
- Overall, on a dollar basis: $81 billion/year
  - Greatly outweighs $1.5 billion/year program cost

Other Considerations for Users

- **Healthier workers & families--** Those who live and work around diesels will especially benefit from greatly reduced exhaust toxicity

- **Better Running Engines** (including existing fleet) from sulfur removal
  - Sulfuric acid corrodes cylinder liners, rings, exhaust system
  - Acid also degrades lube oil-- oil change intervals will be extended

- Proposal applies **only to new equipment**; does not mandate retrofits

- Nonroad and highway fuel will be **essentially identical** for the first time in 18 years -- could potentially simplify on-site tankage

Next Steps

- **Public Hearings were held in June**
- **Comment period** open until August 20
- **Final rule** in Spring 2004
  - Advance notice for new locomotive and marine diesel engine standards

- Copy of proposal and supporting documents are available from:

  www.epa.gov/nonroad/

- Specific questions:

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  charmley.william@epa.gov